Journal of Archaeological Science 51 (2014) 154–163

Contents lists available at SciVerse ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

The Neolithic woodland – archaeoanthracology of six Funnel Beaker sites in the lowlands of Germany

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ARTICLE INFO

Article history:
Received 31 January 2012
Received in revised form
11 October 2012
Accepted 26 October 2012
Available online 2 November 2012

Keywords:
Natural environment
Human impact
Maloideae
Archaeoanthracology
Neolithic
Northern Germany

ABSTRACT

Charcoal from six Neolithic Funnel Beaker sites in the lowlands of Germany was investigated, providing information on the woods used at these sites. The species assemblages reflect the composition of the woodlands surrounding the sites, and represent the individual natural site conditions. Two of the sites are situated in wetlands (Oldenburg and Wolkenwehe). Here, high values of *Alnus* and *Fraxinus* were found, both typical taxa on wet soils. These taxa are also common at sites with a smaller proportion of wetlands (Triwalk and Flintbek), where *Quercus* is more important. At the two sites which are situated on dry soils further south-east (Lüdelsen and Belleben), *Quercus* is the dominant taxa, and *Pinus* is more frequent. Besides the reflection of the forest composition, the impact of human activity on the landscapes can be seen in the assemblages. Light demanding species as *Corylus* and Maloideae show high values indicating an opening of the forests by Neolithic farmers. The Maloideae values are only low at Wolkenwehe and Lüdelsen. At Wolkenwehe this can be explained by the potential activity range for wood collection on the surrounding wetlands and at Lüdelsen by nutrient-poor soil conditions, which are also indicated by *Pinus*. An important aspect of charcoal analysis is to compare different sampling methods. In this study, results from handpicked charcoal can be compared with those from floated sediment samples for two sites. Some differences appear, for example higher values of *Pinus* in the floated samples. This may be explained with fragmentation processes or displacement.

1. Introduction

The openness of palaeolandscapes is an issue that is often discussed (e.g. Kreuz, 2008). One subject of this discussion is the natural openness due to herbivores (Mitchell, 2005; Svenning, 2002; Vera, 2000; Whitehouse and Smith, 2010). Another, archaeologically relevant aspect is the anthropogenic landscape opening (Iversen, 1973; Kalis and Meurers-Balke, 1998). Changes in Neolithic subsistence strategy – such as the rise of agriculture and the onset of permanent settlements – resulted in changing land uses. Farmers needed arable fields for cultivation and therefore deforestation of these areas was necessary. After this onset settling period with a start of deforestation, the activity of the people further impacted the woodlands and thereby the openness of the landscape. Humans changed their environment by expanding their cereal fields and pastured areas and by fire wood and timber exploitation. With an extended use of the same place over longer periods the impact on the environment increased and may have affected the wood usages of the Neolithic settlers itself. Wood usages over a long period of time affect the size of the used timber. A shortage is visible, e.g. in the diameter decrease of timber for construction (e.g. Billamboz, 2008; Marguerie and Hunot, 2007).

At the same time, the environment changed due to migration and spread of species. This resulted in the appearance and increase of new and the decrease of already established wood species. Most of these changes took place during the Mesolithic period. However, the immigration of *Fagus sylvatica* (European Beech) into Central Europe coincided with the Neolithic period (Lang, 1994). These processes of areal extensions are well-documented for most woody species in pollen diagrams. The discussion on the actual presence of a taxon in a region continues and cannot be proven based solely on pollen studies. Reliable evidence of an early occurrence is possible with the dating of macro remains (Kullman, 1995, 1998).

Pollen analysis enables the reconstruction of vegetation changes on a regional scale and with a broad taxonomic base. In contrast, wood charcoal analysis in archaeological contexts (archaeoanthracology, Vernet, 2002) is focused on the used wood

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0305-4403/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jas.2012.10.024

spectra (e.g. Asouti and Austin, 2005; Badal et al., 1994; Dufraisse, 2008; Figueiral, 1996; Heinz and Thiébault, 1998; Heiss and Oeggl, 2008; Salisbury and Jane, 1940; Thiébault, 2002). Along with other carbonized material (fruits and seeds) it provides the only possibility to obtain information on the usage of wood resources by the people in non-waterlogged contexts. Wood was the most important construction and tool material, as well as an energy source of the Neolithic societies. The acquisition of wood was a regular task. Two collection strategies for fire wood are put forward by Marston (2009): One is based on the "principle of the least effort" (Shackleton and Prins, 1992), in which all available taxa were used resulting in a taphonomic spectrum representing the wood taxa of a site's vicinity. The second is based on the selection of wood species for different functions resulting in a spectra affected by the selection factors. For example, it is postulated that soft wood species such as *Tilia* or *Salix* were not used as fire wood because of their inferior burning qualities (low calorific value), while hard wood species like members of the Rosaceae family, especially of the subfamily Maloideae, were preferred (Kreuz, 1990, 1992; Out, 2010). Even if some species are over- and under-represented due to preference and avoidance, it is widely assumed that for the Neolithic period the charcoal spectra represents the available wood in the surroundings of a site and longer transportation of wood was unimportant.

While charcoal was previously analysed from several selected Linear Pottery Culture sites mostly in southern and western Germany and Austria (Kreuz, 1990, 1992, 2008), as well as from Dutch sites of the Swifterbant Culture and Hazendonk Group (Out, 2010), we are now able to give a first, comprehensive insight into the used wood resources of the Funnel Beaker Culture for the German lowlands. Here, we present new wood charcoal data from six Neolithic sites in northern Germany, located in a south-north transect from the more continental Loess area east of the Harz Mountains, to the sub-oceanic Weichselian young moraine area in the north. We aim to investigate 1) which wood taxa were used in the Neolithic, 2) the information about the environment around the sites given by the charcoal spectra, 3) the impact of Neolithic people on the woodlands within their activity range, and 4) if different sampling approaches affect species assemblages.

2. Material and methods

2.1. Study sites

All sites investigated in this study were used during the Funnel Beaker period. According to Müller et al. (2010, Northern Plain Chronology) the culture started in the Early Neolithic (c. 4000 cal. BC) and was replaced by the Single Grave group in the Younger Neolithic (c. 2800 cal. BC). Four of the six sites (Flintbek, Oldenburg, Wolkenwehe, and Triwalk) are situated in North Germany, which has a temperate oceanic climate with a c. 8.5 °C mean annual temperature and approximately 750 mm mean annual precipitation (climatological data of station Kiel Holtenau for the period 1961–1990, German Weather Service [DWD], 2012). The other two sites (Belleben and Lüdelsen) are located in Central Germany, which has a more semi-continental climate with a c. 8.7 °C mean annual temperature and approximately 500 mm mean annual precipitation (climatological data of station Magdeburg for the period 1961–1990, German Weather Service [DWD], 2012) (Fig. 1, Table 1). Today, the woodlands of Schleswig-Holstein are mainly composed of temperate mixed deciduous and planted coniferous forest. *Fagus sylvatica* is the main deciduous tree species. In the area of Belleben and Lüdelsen most forests are afforested with coniferous trees, mainly *Pinus*.

2.1.1. Oldenburg

At present, several archaeological sites are known in the region of the "Oldenburger Graben", a linear depression with fen systems. One of these sites is a Middle Neolithic (3500–3000 cal. BC) settlement situated on a former small island near Oldenburg-Dannau, and surrounded by Weichselian moraine landscape. The site is situated at a 5 km distance from the modern coastline of the Baltic Sea. Since 2009, excavations of this settlement were carried out by the team of Jan Piet Brozio from the Institute of Pre- and Protohistory, University of Kiel (Brozio et al., 2014). To date, several houses, a well, and a settlement burial have been found. The preservation of organic material is very good due to the waterlogged ground. Visible charcoal (handpicked single charcoal, and multiple fragments) was sampled during the excavation from the different features of the settlement layers.

2.1.2. Flintbek

Excavations of the megalithic tomb field of Flintbek by the archaeological state agency of Schleswig-Holstein from 1977 to 1996 yielded archaeological material from the Neolithic period until the Iron Age. The area is located on Weichselian moraine material and bordered by the Eider River to the west and by three mires ("Kleinflintbeker Moor", "Kirchenmoor" and "Fehltmoor") to the east. During the Neolithic period, more than 25 megalithic tombs were built (Diers et al., 2014; Mischka, 2011). Fire was used (for example for the preparation of the chamber ground), thus charcoal was found in several layers. Only visible charcoal was sampled during the excavations, and no charcoal from floated sediment samples was available. Charcoal samples (multiple fragments) were available from various features, such as fire places, flint roast places, and fillings of the grave. The samples were connected to the construction and the usage of the graves. Only samples dating to the Early and Middle Neolithic period were used for the comparison. Diers et al. (2014) compare these charcoal results with new palynological investigations from the region.

2.1.3. Wolkenwehe

The Neolithic station Wolkenwehe is situated within a fen system ("Brenner Moor") of a diameter of about 1 km. The site was discovered in 1950, and shortly afterwards first excavations took place (Hartz et al., 2007). During the time of usage, it was situated on a peninsula in a lake basin. Charcoal was found together with bones and artifacts in a peaty layer overlaying lake sediments. Today, the river Trave borders the fen to the north and to the east. From 2006 until 2009, the team of Doris Mischka and Jan Piet Brozio from the Institute of Pre- and Protohistory, University of Kiel, carried out further excavations (Mischka et al., 2007). The site was used intermittently between 3500–3100, 2800–2700, and 2400–2200 cal. BC. At first it was considered to be a settlement site. However, this is still debated because of the findings and the location in the centre of a river fen complex. It was possibly used as a temporary site and its function is linked with the occurrence of salty springs in the fen. The preservation of organic material is very good thanks to the waterlogged ground.

2.1.4. Triwalk

The settlement is situated on a Weichselian moraine 5 km south of the Wismar bay (Baltic Sea), near Triwalk. It was discovered in the 1970s, but the site was only excavated in 1995 because of the construction of the A 20 motorway. The archaeological findings date to the Neolithic and Bronze Age periods (Staude, 2011). The charcoal samples belong to the Funnel Beaker period dated to the Middle Neolithic (Staude, 2011). As in Flintbek, only charcoal which was seen during excavation was sampled (resulting in samples with few pieces) and available for determination.

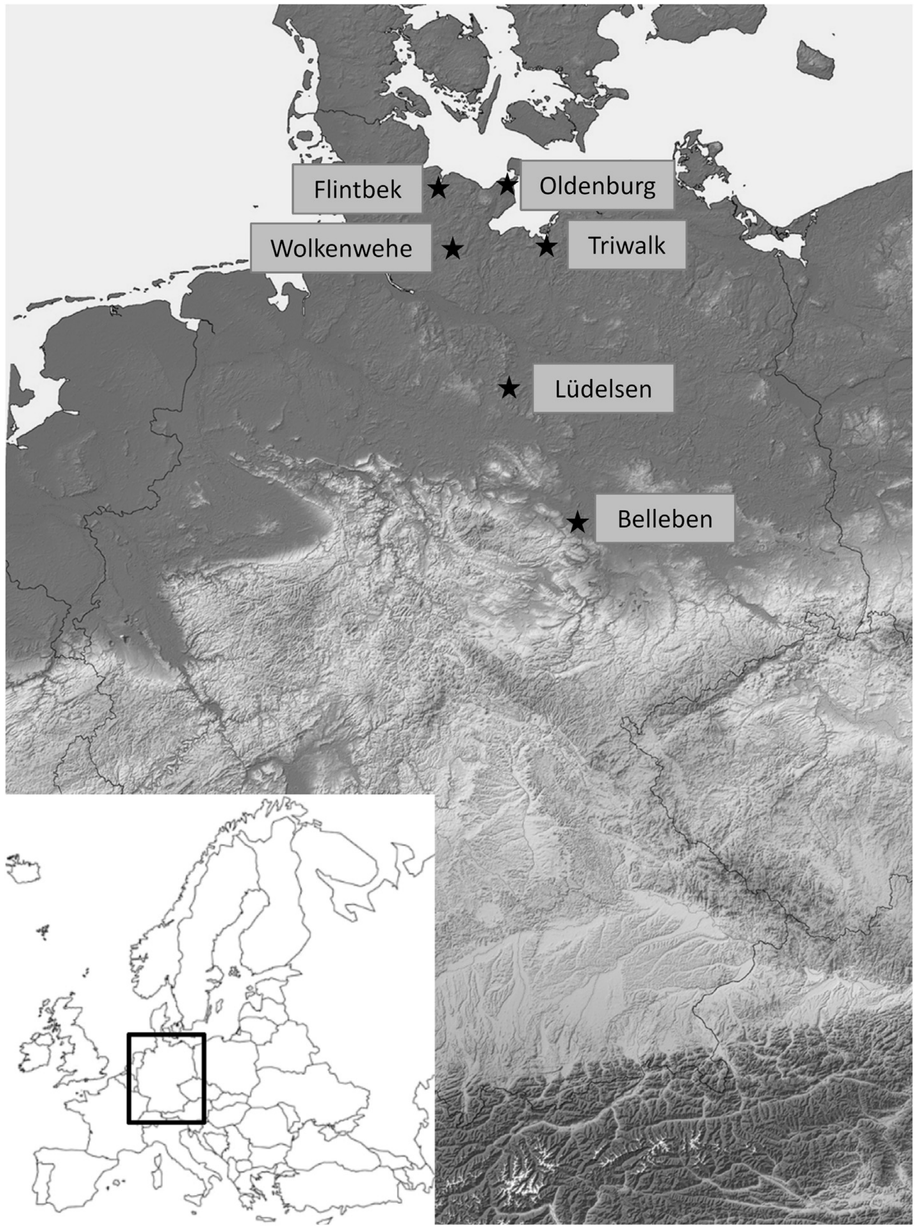

Fig. 1. Study area. (a) Overview; (b) location of the study areas in Northern Germany.

2.1.5. Lüdelsen

A Neolithic megalithic tomb ("Königsgrab") near Lüdelsen in the Altmark was excavated by the team of Denis Demnick from the Institute of Pre- and Protohistory, University of Kiel, in 2009/2010. Further megalithic tombs are located in the direct vicinity (Demnick et al., 2008). The graves of Lüdelsen are situated on the

Table 1
General information about the study sites. *: Present but undetermined samples.

Study site	Coordinates		Site class	Time of excavation	Number of samples		Literature
					Handpicked	Floated	
Oldenburg	54° 17′ N	10° 51′ E	Settlement	Since 2009	129	*	Brozio et al., 2014
Flintbek	54° 15′ N	10° 05′ E	Graves	1977–1996	79		Diers et al., 2014; Mischka, 2011
Wolkenwehe	53° 49′ N	10° 21′ E	Station	2006–2009	190	*	Hartz et al., 2007; Mischka et al., 2007
Triwalk	53° 51′ N	11° 29′ E	Settlement	1995	26		Staude, 2011
Lüdelsen	52° 41′ N	10° 57′ E	Grave	2009–2010	9	34	Demnick et al., 2008; Diers et al., 2014
Belleben	51° 39′ N	10° 37′ E	Enclosure	Since 2005	37	17	Rück, 2012

Saalian moraine in a reforested pine forest. The megalithic tomb was built during the Funnel Beaker period, but human usage is detectable at least until the Iron Age. Traces of former agricultural use are present in the form of an Iron Age/Medieval ridge-and-furrow system surrounding the grave. Only samples connected to Funnel Beaker features were used for comparison. Results from palynological investigations are compared to the charcoal analysis in Diers et al. (2014). Charcoal from handpicked and floated sediment samples was analysed.

2.1.6. Belleben

Belleben is an enclosure with a round extension of about 90 m in diameter near Belleben in Sachsen-Anhalt. The site is situated 5 km west of the river Saale on Saalian moraine debris. Today the area is used for agriculture. Oliver Rück and his team (Institute for Art History and European Archaeology, Martin-Luther-University Halle-Wittenberg) have been excavating the enclosure since 2005. The function of these structures is still a matter of investigation. The enclosure is dated to 3600–3400 cal. BC, and thus belongs to the Baalberge Group (Rück, 2012).

2.2. Anthracology

In connection with the excavations many charcoal samples were extracted – usually in the context with a feature for possible use in subsequent radiocarbon dating. Only in the cases of Lüdelsen and Belleben charcoal was additionally analysed from floated sediment samples. Charcoal pieces larger than 1 mm were identified using wood anatomical atlases by Schweingruber (1990a, 1990b) and the reference collection of charred wood of the Palaeoecology Research group of the Institute for Ecosystem Research, University of Kiel. The fragments were manually broken to gain the necessary fresh surfaces of transversal, tangential and radial orientation. For taxonomical identification, a stereoscope with magnification up to ×112 (Nikon SMZ1500) and an incident-light microscope with magnification up to ×500 (Nikon ME600 Eclipse) were used. Differentiation between *Quercus* and *Castanea* is not possible when only singular-celled rays are visible due to the small sizes of the fragments. However, the occurrence of *Castanea* is highly improbable because the studied sites are far away from the natural range of chestnut trees. Hence, these fragments are added to the *Quercus* values. Similarly, the anatomical differentiation between *Populus* and *Salix* is sometimes not possible and both species are then grouped as *Populus*/*Salix*-type. The anatomical differentiation within the Rosaceae apple fruit family is not feasible, thus the Maloideae includes *Malus*, *Crataegus* and *Pirus* without spiral thickenings. We separated *Sorbus* when thickenings are present (Schweingruber, 1990b). A clear differentiation between both types is not always possible.

The results of determination are presented by percentages of number and weight for each taxon. The diameter of the wood from which the fragment originated was estimated using a diameter stencil (Ludemann and Nelle, 2002; Ludemann et al., 2004; Nelle, 2002a, 2003) in the case of larger fragments (usually at least 5 mm). Based on the visible growth ring curvature combined with the angles of wood rays, a classification into five different diameter classes (<2 cm, 2–3, 3–5, 5–10, >10 cm) was done. Fragments with the outermost growth ring and bark rarely occur, thus it is only possible to measure the minimum wood diameter. For a comparison of taxa and study sites a mean diameter (mD) was calculated with the formula:

$$\mathrm{mD[cm]} = [n(0-2\ \mathrm{cm})*1 + n(2-3\ \mathrm{cm})*2.5 + n(3-5\ \mathrm{cm})*4 + n(5-10\ \mathrm{cm})*7.5 + n(>10\ \mathrm{cm})*15]/n\ \mathrm{total}$$

The resulting values range theoretically between one and 15 cm. Low values (1–3–6 cm) indicate use of thinner tree parts (small and medium sized branches, coppice shoots or young stems), while high values (10–13–15 cm) indicate origin from thicker parts (large branches and trunks). Values of 7–8 cm were gained when analysing reference material from old, formerly coppiced stands with stems of 10–20 cm diameter (Nelle, 2002a).

2.3. Dating

Charcoal was chronologically arranged based on (1) the archaeological context of the individual samples, and (2) in the case of Flintbek on AMS measurements (Mischka, 2011).

Samples connected to the Funnel Beaker period are selected for comparison of the different sites. Not all sites used were exactly contemporaneous or dating to the same time span. Contamination of samples due to pedogenic processes, such as bioturbation, can never be excluded.

3. Results

A total of 530 samples from six Funnel Beaker contexts were analysed. Altogether 4681 charcoal fragments were taxonomically identified (Fig. 2, Table 2). The dataset varies due to the number of analysed samples, which range between 26 (Triwalk) and 190 samples (Wolkenwehe) per site. Altogether 23 taxa were found.

At Oldenburg thirteen taxa were found. The spectrum is dominated by *Alnus* (alder), followed by *Corylus* (hazel) and Maloideae. *Frangula* (alder buckthorn), *Lonicera* (honeysuckle) and *Sambucus* (elder) were only found at this site, together with the rare taxon *Sorbus* (white beam or mountain ash). Sixteen taxa occurred at Wolkenwehe. As in Oldenburg, *Alnus* dominates. *Fraxinus* (ash) and *Corylus* show considerable proportions. *Rhamnus* (purging buckthorn) and *Cornus* (dogwood) appear solely in the Oldenburg spectrum, and the rare taxa *Fagus* (beech) and *Prunus* (sloe, cherry, or plum) can be observed. At Flintbek thirteen taxa were found. *Quercus* (oak) is dominant and *Corylus*, *Fraxinus*, and Maloideae are frequent. *Hedera* (ivy), *Fagus*, and *Sorbus* were found. In Triwalk only six taxa are present. *Quercus*, *Alnus*, and Maloideae are the main taxa. No rare taxa were found. Ten taxa occur at Belleben. *Quercus* is dominant, whereas Maloideae are frequent. *Carpinus* (hornbeam) only was found in Belleben and additionally the rare taxon *Prunus*. At the Lüdelsen site, nine taxa were detected. *Quercus* and *Pinus* type *sylvestris* (pine) are the main taxa and Ericaceae only appears in this spectrum. *Betula* (birch) amounts to about 10% at Lüdelsen, but is rare at all other sites. *Tilia* (lime) is frequently present in Flintbek and Oldenburg. Other taxa were found in small quantities: *Acer* (maple), *Populus* (poplar), *Salix* (willow), and *Ulmus* (elm).

In the four northern sites (Flintbek, Oldenburg, Wolkenwehe, and Triwalk) the taxa *Alnus* and *Fraxinus* are frequent. Especially striking are the high values of wetland taxa at the site of Wolkenwehe and Oldenburg. In contrast, these taxa are nearly missing in the two southern, climatically more continental sites (Lüdelsen and Belleben). Instead, *Pinus* has a higher proportion at Lüdelsen. The subfamily Maloideae reaches high values at the sites Belleben (26%), Flintbek (15%), Oldenburg (13%), and Triwalk (25%).

For those sites where only handpicked charcoal fragments were analysed, the spectra percentages based on the weight of the fragments show similar proportions with some small variations. *Alnus* shows slightly higher proportions at Oldenburg and Wolkenwehe, *Quercus* slightly lower ones at Oldenburg and Triwalk. Noticeable in all samples is the low weight of the *Pinus* pieces

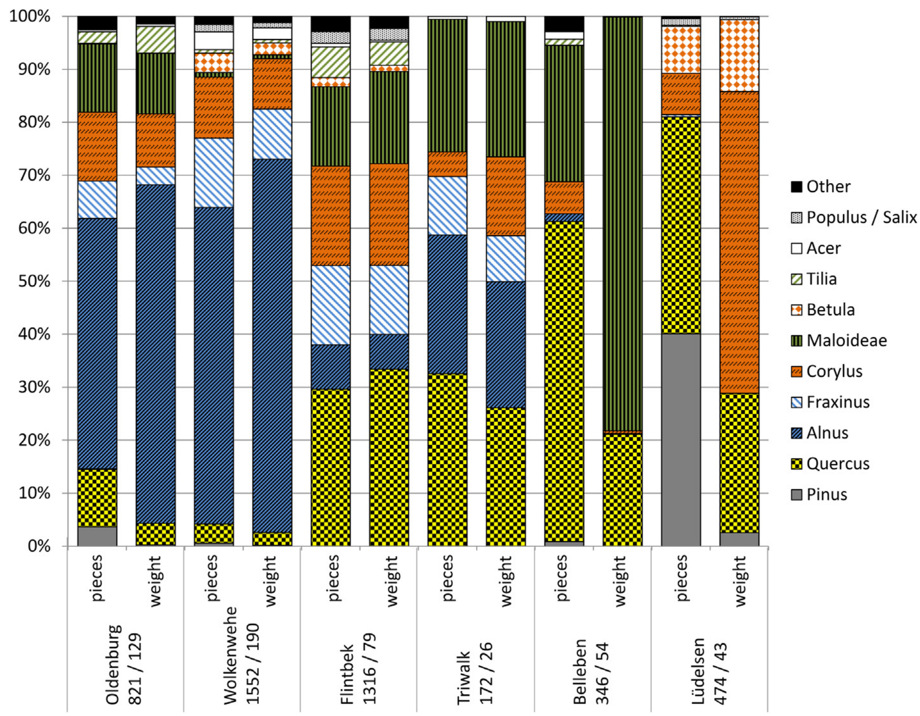

Fig. 2. Charcoal assemblages of all sites by number and weight of fragments. Below the site names numbers of analysed fragments and samples are given. Others include: *Fagus*, *Ulmus*, *Prunus*, *Frangula*, *Sorbus*, *Cornus*, *Rhamnus*, *Lonicera*, *Sambucus*, *Hedera*, *Carpinus* and Ericaceae.

(Fig. 2). For example, in the case of Lüdelsen *Pinus* reaches 40% by number of charcoal pieces and just 2.5% by weight.

A comparison of the two different sampling methods (handpicked at the excavation versus floating of sediment samples) was possible for two sites (Lüdelsen and Belleben, Fig. 3). The total number of taxa (per site and sampling method) as well as the average number of taxa per sample is higher for floated sediment samples. Sizes of charcoal fragments are higher in handpicked samples. *Pinus* just occurs in sediment samples, whereas *Quercus* is frequent in both. At the Belleben site, *Corylus*, *Tilia*, *Acer*, and *Populus*/*Salix*-type are more frequent in the sediment samples and Maloideae is more common in the handpicked ones. In contrast, *Corylus* reaches much higher values in handpicked samples at Lüdelsen. The other taxa show no differences except for *Pinus* values.

The calculation of mean diameters (mD) results in high values for Wolkenwehe and Oldenburg (>7) and low values for Triwalk and Lüdelsen (<6) (Table 2, Fig. 4). *Quercus*, *Alnus*, and *Fraxinus* reach high values at all sites with data excluding Triwalk, *Corylus* and Maloideae show low values. However, the dataset for single sites and taxa is unequal and not always sufficient. For example, for the values of *Quercus* (which occurs at all sites) the dataset is very good (>100 pieces) for Flintbek, moderate (>30 pieces) for Wolkenwehe and Oldenburg, but poor for Triwalk, Lüdelsen, and Belleben (<30 pieces).

4. Discussion

4.1. Differences due to sampling methods

The material bases when using samples of archive material, rescue excavations, or research excavations differ considerably. Generally, only low numbers of charcoal samples are available from rescue excavations, as in the case of Triwalk. The comparison of the two sites with burial contexts (Flintbek and Lüdelsen) shows that for the former case (Flintbek) only archive material was available. Here, we profit from the high number of megalithic tombs that had been excavated. Results from individual graves are very difficult to interpret, but in total much charcoal was sampled. At Lüdelsen, extensive sampling was carried out during the research excavation. This enables us to gain comparable results (to Flintbek) from one grave. Nevertheless, a sufficient number of samples were available from all sites to obtain an insight into wood selected for use, though more samples would have yielded more precise information.

A research excavation usually yields the best dataset with the application of different sampling methods. Moreover, samples are usually taken by the excavators in collaboration with botanists. This underscores the importance of collaboration between archaeobotanists and archaeologists, which begins at the excavation at the earliest and not at the laboratory phase.

The charcoal results from handpicked and floated sediment samples differ significantly. For some species, selective fragmentation seems to play a role (as for *Pinus*). Chabal (1992) and Théry-Parisot et al. (2010) did not find significant differences in fragmentation between *Quercus*, *Ulmus*, *Alnus*, *Populus*, and *Salix* at the archaeological sites of Le Marduel and Lattara (France). However, no coniferous charcoal is presented in their comparison. In our material the differences for *Corylus* – which has a higher proportion at Belleben in the sediment samples and at Lüdelsen in the handpicked samples – are hard to explain by fragmentation. Similarly, the total absence of *Pinus* in the handpicked samples cannot be explained by fragmentation.

If fragmentation cannot serve as explanation alone, other reasons should be included. Most sites were used over a longer time span. This can affect the datasets used for the comparison of methods because these are comparatively small and may randomly include different time spans during the Funnel Beaker culture. Further, due to the smaller fragment size of charcoal from sediment samples, a displacement by animal activity is more probable (Canti, 2003). In this context, it should be taken into account that forest

Table 2
Results of charcoal analysis from the sites. *n*: number of fragments; *n* mD: number of charcoal suitable for diameter measurement; mD: mean diameter; *W*: weight [g].

	Oldenburg				Wolkenwehe				Flintbek				Triwalk				Belleben				Lüdelsen			
	n	*n* mD	mD	*W* [g]	*n*	*n* mD	mD	*W* [g]	*n*	*n* mD	mD	*W* [g]	*n*	*n* mD	mD	*W* [g]	*n*	*n* mD	mD	*W* [g]	*n*	*n* mD	mD	*W* [g]
Acer	3	1	2.5	0.4	52	44	7.7	11.4	9	1	10.0	1.6	1	1	2.5	0.4	5	.	.	0.01	.	.	.	.
Alnus	389	154	9.1	56.7	927	780	7.7	361.3	110	39	7.3	29.0	45	16	4.6	10.2	5	1	1.0	0.03	.	.	.	.
Betula	1	1	7.5	0.02	57	40	5.7	11.6	23	7	3.3	5.3	.	.	.	.	.	.	.	.	42	11	1.7	1.4
Carpinus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	0.01	.	.	.	.
Cornus	.	.	.	.	1	1	1.0	0.07	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Corylus	107	38	4.0	8.9	179	144	4.6	48.9	247	160	5.4	84.4	8	2	5.0	6.4	21	.	.	0.1	37	22	6.7	6.0
Ericaceae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	0.01
Fagus	.	.	.	.	3	1	15.0	1.2	15	11	2.0	4.8	.	.	.	.	.	.	.	.	.	.	.	.
Frangula	13	7	9.7	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fraxinus	58	25	8.9	3.0	203	171	9.8	48.6	197	134	8.8	57.3	19	9	5.1	3.7	.	.	.	.	2	.	.	<0.01
Hedera	.	.	.	.	.	.	.	.	3	1	2.5	0.4	.	.	.	.	.	.	.	.	.	.	.	.
Lonicera	1	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Maloideae	106	31	6.4	10.1	13	9	2.9	3.7	197	124	5.7	76.4	43	25	4.0	11.0	89	49	6.6	16.1	.	.	.	.
Pinus	30	7	5.4	0.2	9	3	12.5	0.7	.	.	.	.	.	.	.	.	3	.	.	<0.01	190	22	3.5	0.3
Populus	.	.	.	.	20	7	4.1	3.1	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1.0	0.05
Populus/Salix	.	.	.	.	1	.	.	1.3	18	8	5.8	6.6	.	.	.	.	.	.	.	.	5	.	.	<0.01
Prunus	.	.	.	.	11	10	7.2	2.9	.	.	.	.	.	.	.	.	5	1	1.0	0.01	.	.	.	.
Quercus	89	31	9.3	3.6	56	35	7.0	12.4	390	190	7.8	146.9	56	15	6.6	11.2	209	14	7.8	4.4	194	24	9.0	2.8
Rhamnus	.	.	.	.	7	6	6.3	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salix	.	.	.	.	1	1	4.0	0.4	11	6	6.8	3.1	.	.	.	.	.	.	.	.	.	.	.	.
Sambucus	1	.	.	0.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sorbus	5	1	15.0	0.5	.	.	.	.	6	5	2.8	2.7	.	.	.	.	.	.	.	.	.	.	.	.
Tilia	18	10	14.3	4.5	10	10	10.0	3.2	76	44	8.9	19.3	.	.	.	.	4	.	.	<0.01	1	.	.	<0.01
Ulmus	.	.	.	.	2	2	3.3	0.9	14	8	4.5	2.2	.	.	.	.	1			<0.01	1	.	.	<0.01
Total determined	821	306	8.3	88.8	1552	1264	7.5	512.9	1316	738	6.9	439.9	172	68	4.9	42.9	346	65	6.7	20.6	474	80	5.7	10.5
Bark	26	.	.	13.9	12	.	.	8.3	9	.	.	1.4	.	.	.	.	.	.	.	.	5	.	.	0.09
Indet. deciduous	47	.	.	1.6	8	.	.	2.6	4	.	.	0.5	12	.	.	2.0	73	.	.	0.7	16	.	.	0.09
Indet. coniferous	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	<0.01	2	.	.	<0.01
Indet.	84	.	.	3.9	6	.	.	5.8	23	.	.	7.9	.	.	.	.	34	.	.	0.6	141	.	.	0.2

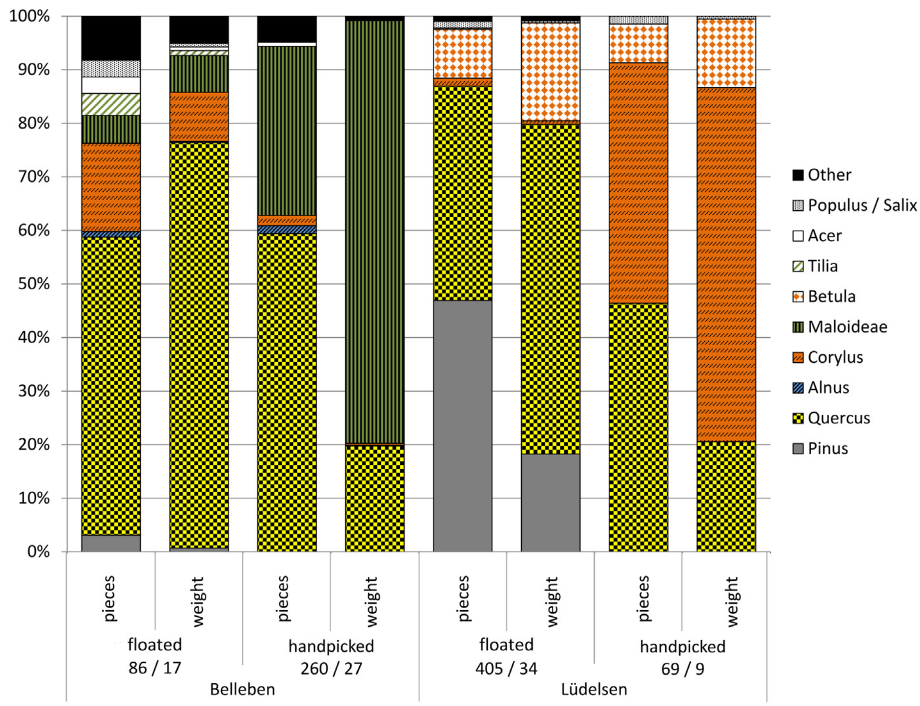

Fig. 3. Charcoal assemblages for the sites Belleben and Lüdelsen divided into categories 'handpicked' and 'floated' sediment samples by number and weight. Below the sampling method numbers of analysed fragments and samples are given. Others include: *Ulmus*, *Prunus*, *Carpinus* and Ericaceae.

fires before the construction of the grave may result in higher values of (older) *Pinus* in sediment samples. This might be due to subsequent relocation by e.g. bioturbation, or soil sediments were moved during construction and use. Thus, the handpicked charcoal samples may reflect predominantly the wood use in the grave context. However, the number of samples and identified charcoal pieces is still low but the comparison gives a first hint. Though cautiously interpreted at this stage, the sampling method seems to

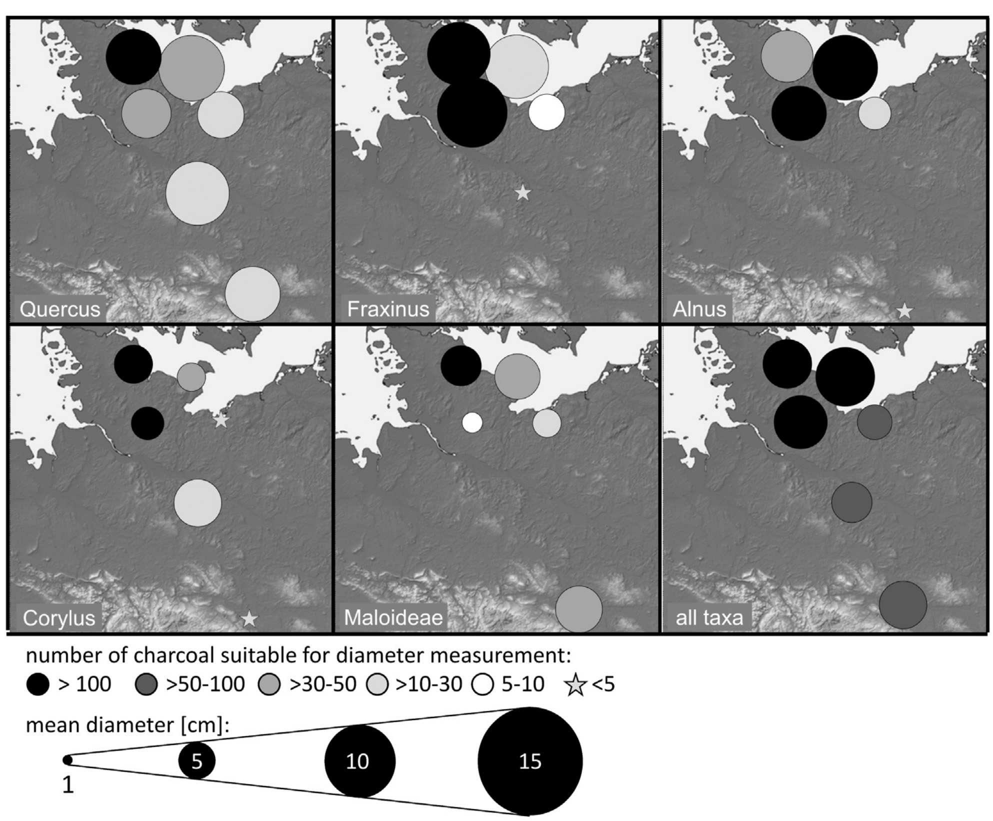

Fig. 4. Illustration of the mean diameter (mD) for selected taxa (*Quercus*, *Fraxinus*, *Alnus*, *Corylus* and Maloideae) and the overall charcoal assemblages at the individual sites. The sizes of the circle symbolize the mD and the colour the number of fragments.

affect the charcoal spectra. Thus, a comparison of handpicked and sediment samples should be done with care, and further examples are necessary to evaluate the influence of the sampling method. Nevertheless, both sampling types are necessary for example on sites with low charcoal quantity (see Belleben and Lüdelsen), where even the sediment samples contain often just a few fragments. We assume that both spectra together represent the woodland environment whereas the handpicked samples might better represent human usage of wood, and the sediment samples the total spectra (Théry-Parisot et al., 2010), with a higher amount of older, displaced charcoal.

4.2. Indicators for openness and natural woodland in the charcoal assemblages

The woody species composition and growth of single species is affected by various factors (Schweingruber, 1993, 1996). One factor is the ability to produce coppice shoots after cutting, which differs between species. For example, *Quercus* and *Corylus* are able to produce shoots even after repeated cuttings (e.g. Joys et al., 2004) whereas *Pinus* does not. Another factor is the germination of new woodland stands on a clearing where pioneer species such as *Pinus* and *Betula* may establish faster than others. Exploitations as coppice or limitation of large diameter wood would lead to a reduction in the diameter of used wood (Billamboz, 2008; Marguerie and Hunot, 2007; Nelle, 2002b). The mean diameter values of the summarised assemblages, and those of summaries for single species show that different sizes of wood were used. The high values of *Quercus*, *Fraxinus* and *Alnus* indicate that considerable diameters like large branches and trunks were available in the surroundings and used possibly for construction purposes (Nelle, 2002b). Thus, there is no indication that the resources for large diameter wood were limited. The lower values for *Corylus* and Maloideae can be explained by their shrub growth morphology. Unlike the other sites, Triwalk shows surprisingly low mean diameter values for all species. However, due to sampling conditions and the low number of samples this cannot be interpreted in detail. At a late Neolithic site at Lac de Chalain, *Fagus*, *Quercus*, *Fraxinus* and *Corylus* were predominantly used (Dufraisse, 2008). There, the measurements of wood diameter indicate, in contrast to our data, mostly small to medium sized wood of these taxa were utilised.

The way an area is used economically plays an important role. Keeping livestock promotes the growing of species as *Crataegus* sp., being more resistant to grazing due to morphological or physiological adaptions, and thus are avoided by animals. The availability of light in a stand has a decisive influence on germination, establishment and growth. A woodland which is used for wood exploitation or pasture exhibits a less dense canopy, thus better light conditions promote certain species like *Corylus* and members of the Maloideae. As a consequence, they are more common in a human activity range, and presumably used in higher proportions for e.g. fire wood.

The charcoal spectra show both, 1) the natural conditions of each single site and 2) changes due to human impact. High values of light demanding taxa indicate an opening of the landscape around most of the sites excluding Wolkenwehe (see below). In the case of Lüdelsen, light demanding Maloideae are absent. This can be explained by the poor sandy soils of the Altmark region which is not suitable for these species. Hence, it is hard to estimate the opening by humans because the values of *Corylus* (which are comparable to the values of the other sites) may be caused by naturally higher light availability in an oak forest with pine (see also Diers et al., 2014). *Corylus* clearly profits from woodland openings and land use. The explanation of high Maloideae values is open to discussion, because fragments cannot be narrowed down to the genus level (Damblon et al., 2001/2002; Kreuz, 1992). Two different scenarios are possible: 1) due to grazing of livestock pasture weeds became more common in the surroundings of settlements. Today, this is observed in natural conservation areas with low intensity grazing, where *Crataegus* benefits from this land use. *Crataegus* then became a frequently used fire wood (with a high calorific value per volume), because it grew near to the settlement in the pastured area, and its removal from the pastures was also a kind of caring work. 2) The second scenario supposes a direct promotion of *Malus* for apple production. Macro remains of apples are commonly found in Neolithic settlements like in Oldenburg (Brozio et al., 2014). However, it is difficult to imagine that such amounts of fire wood were derived from apple trees without affecting the apple production. However, a combination of both is possible. Kreuz (1990, 1992, 2008) investigated the charcoal from ten sites of the early Neolithic Linear Pottery Culture. The charcoal spectra are dominated by *Quercus*, *Fraxinus* and *Pinus* and at two sites the Maloideae show comparable values to our sites but the values of *Corylus* are low. Kreuz (1990, 1992) postulated the usage of hedges during the Neolithic. In addition to being a wood resource, both taxa were used for nut and berry collection and may be as a fence for the livestock. Investigations in the coastal region of the Netherlands show that Maloideae reach very high proportions in the archaeological charcoal records as well, together with *Alnus* (Out, 2010). Out assumes that the Maloideae were selectively used due to their good combustion qualities.

Based on the theory that for fire wood supply the least necessary effort was chosen, we think that the charcoal spectra represent the woody environment of the Neolithic sites. Kreuz (1990, 1992) suggested a selection for the Linear Pottery Culture sites because for example *Tilia* was absent in the charcoal spectra. She explained this absence is due to bad combustion properties. At the two sites Flintbek and Oldenburg, *Tilia* is well represented and we can exclude an avoidance of this species. The values of those species which are less affected by canopy opening and grazing represent the composition of the forest nearby the sites, and we can consequently differentiate between used forest types. At Wolkenwehe and Oldenburg high amounts of *Alnus* and *Fraxinus* were used, probably as fire wood as well as construction timber. The site Wolkenwehe is situated in an extensive mire complex, thus mainly wood from the carr vegetation of the mire was used, and the people did not go beyond the surrounding carr for greater proportions of their fuel wood supply. Due to the size of the mire we estimate that most of the used wood was coming from a distance of 500–700 m from the site. Beyond that distance, there must have been a mixed oak woodland on dry, mineral soils, which is not represented in the charcoal assemblage. This reconstructed resource exploitation range also shows that the carr vegetation was sufficient for their needs. The sites Flintbek and Triwalk also have high values of wetland taxa but in addition *Quercus* is more important. Here, it seems that nearby wet and drier forests where used. At Belleben and Lüdelsen *Fraxinus* and *Alnus* are of no importance. Instead, *Quercus* and in the case of Lüdelsen *Pinus* becomes more important indicating relatively dry, mineral soils. At Belleben, wetter sites – streams or rivers – are further away, thus the nearby absence of *Fraxinus* and *Alnus* fits with the topographic position of the enclosure.

4.3. Comparison to pollen data

Human activity and land use is usually reconstructed by pollen analysis. Pollen grains are often preserved in peats or lake sediments but poorly in mineral soils and deposits. Hence pollen analyses at archaeological sites are rare, depending on the sites

situation. But with increasing distance of the pollen archive from the area of human activity, the influence of taxa promoted by humans decreases (Behre and Kucan, 1986). Further, depending on the size of the mire or lake, the pollen source area is different, thus limiting the results of pollen analysis for answering the question of human impact on local scale (Sugita, 1994; Tauber, 1965).

Changes of certain taxa in the pollen diagrams may be correlated with deforestation and agriculture. These cause a decrease of forest taxa (*Tilia*, *Fraxinus* and *Quercus*) and an increase of indicators for open land (*Corylus*, *Plantago lanceolata*, Poaceae and Cerealia). Iversen (1973) describes three different stages of the so-called "landnam" in the Neolithic for Denmark: forest clearance, agriculture and reforestation.

For Schleswig-Holstein, a high resolution pollen diagram from annually laminated lake sediments of the Belauer See is available for comparison to the charcoal data (Dörfler et al., 2012; Wiethold, 1998). A closed, oak dominated forest existed until the Middle Neolithic period. With the start of the Middle Neolithic period increasing values of *P. lanceolata*, *Rumex acetosella*, Poaceae and Cerealia indicate more intense human activity in the surrounding area of the Belauer See. Due to its regional pollen influx, this diagram shows the general trend for the region rather than human activity at single settlements.

For the two sites Flintbek and Lüdelsen, a comparison of pollen analysis, charcoal results and archaeology is presented in Diers et al. (2014). In the case of Flintbek the first burial phase is slightly visible in the pollen diagram whereas the charcoal assemblage shows clear evidence of human changes in the wood spectra. For the sites Belleben and Triwalk, no pollen diagrams exist. In the fen complex of Wolkenwehe, Dörfler analysed a profile including the time of the usages of the site (Mischka et al., 2007). The local alder carr vegetation at the fen margins and mixed oak forest from the surrounding areas were reflected in these pollen assemblages. The values of species indicating settlement activity are very low. The comparison of the local pollen spectra and the wood uses are complementary and strengthen the interpretation that the site was not used on a permanent basis.

A combination of pollen and charcoal records is useful because pollen highlights the development on a finer temporal and taxonomical scale but often lacks information on the spatial scale (Nelle et al., 2010). On the other hand, charcoal provides information on forest uses and thus reflects the local availability of wood. Additionally, some species present in the charcoal assemblages are poorly represented in pollen diagrams due to low pollen production and/or insectiferous pollination strategies. Especially the Maloideae group has an important part in the charcoal record, but is rarely found in pollen spectra.

5. Conclusion

The charcoal assemblages indicate that the Funnel Beaker people changed the woodland composition. This is mainly indicated by high proportions of the light demanding taxa *Corylus* and Maloideae. On the other hand, the pollen diagrams show for this period only small openings of the mid Holocene wooded landscape in Northern Central Europe. Most of the woodland was still hardly affected by humans, thus a natural landscape existed during the Funnel Beaker culture. However, within the activity range of the Neolithic farmers the woodland was opened on a small, but noticeable scale.

In summary, the settlements Oldenburg and Triwalk, and the station Wolkenwehe are located near or in a wet environment, which is reflected by higher proportions of wetland species. At the grave sites Flintbek and Lüdelsen and the enclosure Belleben, species of dry lands were more important for the Neolithic people. Indicators for openness are only missing in Wolkenwehe due to the usage of an alder carr vegetation, and may be due to an irregular usage of the site, with a less intense impact on the surrounding woodland on mineral soil sites.

The two different sampling techniques (handpicked versus floated sediment samples) results in different taxa compositions. Floated samples contain more taxa per sample and in the overall spectra. The higher values of *Pinus* in the floated samples, together with the low weight of the *Pinus* fragments indicate that selective fragmentation of individual species provide one clue for the difference noted.

Acknowledgements

We thank D. Mischka, J. P. Brozio, K. Staude, O. Rück, D. Demnick and S. Diers and their colleagues for co-operation, sample supply and discussions. This research is funded by a grant of the DFG (Deutsche Forschungsgemeinschaft) financed Graduate School "Human Development in Landscapes" at the University of Kiel towards Doris Jansen. We are grateful to E. Kücükkaraca for proofreading and correcting the English and to the guest-editor N. Whitehouse and the anonymous reviewers for their valuable comments which helped improving an earlier draft of the manuscript.

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